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3. Methods

The interdisciplinary character of the research topic required the application of field and desk research methods used in landscape ecology, pedology, phytosociology and mycology.

3.1. Landscape ecology methods

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Preliminary identification of the location and scale of the phenomenon of land abandonment in the buffer zones of landscape parks in the Łódź Voivodeship was conducted as desk research. Identification of abandoned lands was performed on the basis of visual interpretation of orthophotomaps from 2009, made available by Geoportal (www.geoportal.gov.pl) as part of the Web Map Service (WMS). The basic areas of evaluation were squares of 25 ha each (500 x 500 m), with coordinates declared in the Quantum GIS 1.8.0 software. A total of 33 692 basic squares were interpreted during the research project.

Five intensity classes were used for evaluating the share of abandoned lands in the basic squares:

- class 0: no abandoned lands present among farmlands (0%),
- class 1: low intensity of land abandonment (0.1–25%),
- class 2: medium intensity of land abandonment (25.1–50%),
- class 3: high intensity of land abandonment (50.1–75%),
- class 4: very high intensity of land abandonment (75.1–100%).

Identification of abandoned lands based on interpreting the image of vegetation cover is difficult, as contours of the abandoned lands and other types of land cover are not clear. Young abandoned lands are very similar to the image of some pastures on the orthophotomaps (Faliński 1986). In this work, abandoned lands are defined as those which (Majchrowska 2014):

- are characterised by forest, thicket and grassland or mixed vegetation cover, resulting from secondary succession,
- were cultivated in the past,
- were not artificially afforested or urbanised.

Orthophotomap interpretation resulted in creating a map of abandoned land occurrence. In order to restrict the analysis only to areas related to agricultural activity, anthropogenic areas, forests, inland waters were excluded from the evaluation. The above areas were excluded using land cover classes from the Corine Land Cover programme (Corine Land Cover 2012).

For the purposes of explaining natural factors which influence the spatial pattern and intensity of land abandonment in the analysed buffer zones around landscape parks, the authors prepared maps of natural landscape units – partial geocomplexes, referred to as morpholithohydrotopes. These units represent a specific habitat potential, which results from the geomorphological location, lithological and petrographic character of surface deposits, and their properties related to aeration and moisture.

Geocomplexes were delimited using the method of leading factors, described among others by A. Richling (1982, 1993). Land relief, lithology of surface formations and moisture conditions were selected as the most important geocomponents which influence the habitat potential. The importance of the surface shape and geomorphological location for the dynamics of habitat functioning was decisive for the selection of relief as a delimitation criterion. Lithology of surface formations was chosen due to its influence on the hydrotrophic properties, which naturally predispose lands for specific forms of usage (Krysiak 1996). Moisture conditions, accepted as the third delimitation criterion, are commonly recognised as important for shaping and differentiating habitats, influencing the dynamics of biological transformations and circulation of matter in the habitat (Oświt 1977). The water factor was used for grouping the delimited morpholithohydrotope types into lithogenic geocomplexes – which normally do not undergo excessive moisturising, semi-hydrogenic geocomplexes – shaped partially by periodical anaerobiosis, and hydrogenic geocomplexes – which exist in the conditions of long-term or permanent anaerobiosis. The presented typology of partial geocomplexes refers to earlier divisions introduced for the central part of the Pilica basin (Krysiak 1997, 1999a) and the Łódź Voivodeship (Papińska 2001; Majchrowska 2002). The following maps were used for mapping the geocomplexes: 1:10 000 and 1:25 000 scale topographic maps, Detailed Geological Maps of Poland (SMGP) at the scale of 1:50 000, and soil and agricultural maps of former voivodeships: Łódź at the scale of 1:50 000, Piotrków, Sieradz, Skierniewice, Radom and Kielce at the scale of 1:100 000 prepared by the Institute of Cultivation, Fertilisation and Pedology (Instytut Upraw Nawożenia i Gleboznawstwa) in Puławy (Województwo miejskie łódzkie. Mapa glebowo-rolnicza. 1986; Województwo piotrkowskie. Mapa glebowo-rolnicza. 1979; Województwo sieradzkie. Mapa glebowo-rolnicza. 1977; Województwo skierniewickie. Mapa glebowo-rolnicza. 1988; Województwo radomskie. Mapa glebowo-rolnicza. 1984; Województwo kieleckie. Mapa glebowo-rolnicza. 1985). Maps of geocomplexes were prepared with the use of ArcGIS 10.2.2 software. For all areas included in the research, the respective sheets of SMGP were scanned, and then georeferenced. In this form, they were used as a basemap for drawing – vectorisation of geocomplex limits, based on the interpretation of geological delimitations, in accordance with the table of morpholithohydrotopes of Central Poland (Tab. 3.1).

Morpholithohydrotope maps were prepared using the lithological categories from Detailed Geological Maps of Poland at the scale of 1:50 000:

- for areas on the Pilica river: Balińska-Wuttke 1960; Jurkiewicz 1962; Grzybowski, Kutek 1966; Makowska 1970a, 1970b; Szajn 1978, 1981; Kwapisz 1981; Ziomek 1982, 2001; Kurkowski, Popielski 1986; Janiec 1988; Kłoda 1988; Szałamacha 1989; Brzeziński 1990; Nowacki 1990; Trzmiel 1990; Turkowska, Wieczorkowska 1992; Włodek 2009;
- for areas on the Warta river: Baliński 1994; Baliński, Gawlik 1983; Bezkowska 1991; Haisig, Wilanowski 1979; Haisig, Wilanowski 1994; Haisig, Wilanowski 2000; Klatkowa 1985; Krzemiński, Bezkowska 1984; Sarnacka 1967; Skompski 1967; Ziomek, Baliński 2007; Ziomek, Gałązka 2013, and a 1:50 000 geotouristic map: The Załęcze Landscape Park and the Surrounding Areas – the Wieluń Upland (northern part of the Polish Jura) (Janus, Obarowska 2011);
- for areas around the Bolimów Landscape Park and the Łódź Hills Landscape Park: Balińska-Wuttke 1958, 1960; Różycki, Kulczyński 1962; Brzeziński 1984, 1986, 1990, 1995; Trzmiel, Nowacki 1984; Nowacki 1990; Trzmiel 1990; Klatkowa, Kamiński, Szafrańska 1991; Szalewicz 1993; Szalewicz, Włodek 2009; Włodek 2009; Ziomek, Włodek 2010.

The comparison between maps of land abandonment intensity with maps of geocomplexes (morpholithohydrotopes) was carried out using ArcGIS software. The built-in algorithm of intersection was used for isolating the geometric intersection between the geocomplex layer and the layer of land abandonment intensity classes. The result was a table composed of attributes of both processed layers. Then, using the Haskell programming language, an algorithm was created to group the ArcGIS output data. Application of the algorithm allowed to calculate the percentage share of land abandonment intensity classes in relation to geocomplex types and the percentage share of the area of geocomplex types in classes of land abandonment intensity.

The spatial identification of abandoned lands made it possible to isolate areas of their higher concentration, which were later used for selecting thirteen groups of study plots: Glinnik, Celestynów, Sulejów, Piskorzeniec, Wola Życińska around the Pilica Landscape Parks; Weronika, Wola Pszczółecka, Krzętle, Raciszyn around the Sieradz Landscape Parks; Polesie, Wola Makowska in the buffer zone of the Bolimów Landscape Park; Szymaniszki, Łagiewniki in the buffer zone of the Łódź Hills Landscape Park (Fig. 2.1). In each group, three study plots: A, B, and C were selected for phytosociological and mycological inventorying

Table 3.1. Morpholithohydrotope types of Central Poland

TYPES OF MORPHOLITHOHYDROTOPES OF CENTRAL POLAND	
LITHOGENIC GEOCOMPLEXES (morpholithohydrotopes which do not undergo excessive moisturising)	
Lithogenic geocomplexes associated with outcrops of solid rocks	
1	Outcrops of siliceous rocks
2	Outcrops of carbonate and marl rocks
Lithogenic geocomplexes associated with permeable Quaternary sediments	
4	Boulders, cobbles, gravels, sands and muds of moraine hills and kame hills
6	Glacial and fluvioglacial boulders, cobbles, gravels, sands and muds of plateaus, alluvial fans and erosional-accumulational terraces
7	Sands, silts and muds in bottoms of dry valleys (diluvia)
8	Fluvial sands and gravels of upper terraces
9	Fluvial sands and muds of lower terraces
19	Fluvial sands and muds of flood plains
14	Cover silts of plateaus
15	Aeolian sands of dunes and shields
20	Periglacial cover sands and silts of plateaus
Lithogenic geocomplexes with hydrologic conditions shaped partially by shallow low permeable formations	
5	Glacial tills of plateaus
16	Glacial and fluvioglacial sands and gravels upon glacial tills of plateaus
17	Cover silts upon glacial tills
18	Periglacial and aeolian sands upon glacial tills of plateaus
3	Clays, claystones, muds and mudstones of various origins
SEMI-HYDROGENIC GEOCOMPLEXES (morpholithohydrotopes shaped partially by periodic anaerobiosis)	
13	Mineral and organic formations in depressions of kettle holes, blowouts, spring niches and basin valleys
HYDROGENIC GEOCOMPLEXES (morpholithohydrotopes shaped partially by long term or permanent anaerobiosis)	
10	Fluvial sands, muds and organic sediments of terraces
11	Fluvial sands, muds and organic sediments of valley bottoms
12	Peats and mucks of wetlands

Source: own elaboration.

and evaluating the agrophysical and agrochemical properties of the habitats. The characterisation of each of the study plots consisted of: geographical coordinates, a set of photographs, description of soil profile, tables with results of agrophysical and agrochemical analyses, characteristics of the flora and fungi. Location of the central point of each plot was determined with geographical coordinates with the use of a GPSmap 62s device. The physiognomy of the surrounding area was documented photographically in a hexagonal system. With the camera placed on a tripod, the optical axis of the lens was pointed in six directions on the basis of compass readouts, for azimuths of 0°, 60°, 120°, 180°, 240° and 300°. After presentation of the documented plots, there is a short summary of characteristics for each study plot group.

3.2. Pedological methods

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During field works, soil samples for laboratory analyses were taken from excavated soil pits and drillings with manual augers. Analyses of the sampled sediments were conducted in the District Chemical and Agricultural Station (Okręgowa Stacja Chemiczno-Rolnicza) in Łódź (accreditation certificate for the research laboratory No. AB 820). The following values were calculated using analytical methods:

– granulometric composition and specific surface area, using the laser diffraction method, in accordance with research procedure PB 34, edition 1 of 03.07.2006,
– total nitrogen content (N), using Kjeldahl's titration method (PB 49, edition 2 of 01.02.2007),
– pH in KCl, pH in H_2O (PN-ISO 10390: 1997),
– available phosphorus content (P_2O_5), using spectrophotometric method (PN-R-04023: 1996),
– available potassium content (K_2O), using flame photometry (P-N-R-04022: 1996+Az1: 2002),
– available magnesium content (Mg), using flame atomic absorption spectroscopy (FAAS) (PN-R-04020: 1994+Az: 2004 p. 4),
– content of exchangeable alkaline cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}), using Pallmann method (PB 47 edition 1 of 09.07.2004),
– hydrolytic acidity using Kappen's method (PB 33 edition 1 of 07.09.2004),
– humus content, calculated from organic carbon contents (C org.), determined using titration method (PB 29 edition 1 of 07.09.2004).

The obtained results allowed for such indicators of habitat quality to be determined as: organic carbon to general nitrogen ratio – C/N, cation exchange capacity – T, total bases – S, and degree of saturation with exchangeable alkaline cations – V.

3.3. Phytosociological and mycological methods

Jolanta Adamczyk

Botanical and mycological field observations were conducted in the years 2012 and 2013. The abandoned agricultural lands were identified in buffer zones around all landscape parks in the Łódź Voivodeship: Bolimów Landscape Park, Warta–Widawka Interfluve Landscape Park, Przedbórz Landscape Park, Spała Landscape Park, Sulejów Landscape Park, Załęcze Landscape Park, Łódź Hills Landscape Park. In the abandoned land areas, after preliminary selection, 39 study plots arranged in 13 study plot groups (Fig. 2.1) were chosen. The location of each study plot was precisely marked using the GPS system. In each study plot, the current flora, macromycetes and vegetation were inventoried. The flora and vegetation were evaluated once per each plot, but the fungi were observed 10–12 times during the period of 2 years. Phytosociological and mycosociological releve analyses were carried out in each study plot. Species of flora and lichens were estimated in percentage of land cover in each analysed plot, whereas for species of macromycetes, the estimation of the number of identified occurrences in the study plot was used. Data from observation of the vegetation cover were processed using Ward's hierarchical cluster analysis and IndVal of Dufrene and Legendre (1997).

Nomenclature of plant species was taken from Z. Mirek et al. (2002), mosses – from R. Ochyra et al. (2003), and of fungi and lichens in accordance with Index Fungorum (www.indexfungorum.org/Names/names.asp).